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NAVY INVENTORY MANAGEMENT DECISION-MAKING

by

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The General Accounting Office (GAO) has stated that the Department of Defense (DoD) believes it is better to overbuy inventory items than to manage with just the right amount of stock. This thesis asserts that Navy inventory managers do not have a general tendency to overbuy items, but rather make rational purchasing decisions influenced and motivated by the environment of rewards and penalties in which they work. It is also asserted that Navy inventory managers are risk adverse due to the nature of their environment. Personal stockout costs are examined as one of the key factors influencing decision-making and risk adverse behavior. This thesis introduces a conceptual model that describes the Navy inventory management decision-making environment. This model shows the relationship between personal stockout costs, required service levels, cost considerations, and planning horizons across the different decision-making levels in the Navy. This study concludes that readiness-based performance measures must be changed to incorporate a cost focus, and that the risk facing inventory managers due to personal stockout costs needs to be reduced to change their behavior if lower inventory levels are desired.

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NAVY INVENTORY MANAGEMENT DECISION-MAKING

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ABSTRACT

The General Accounting Office (GAO) has stated that the Department of Defense (DoD) believes it is better to overbuy inventory items than to manage with just the right amount of stock. This thesis asserts that Navy inventory managers do not have a general tendency to overbuy items, but rather make rational purchasing decisions influenced and motivated by the environment of rewards and penalties in which they work. It is also asserted that Navy inventory managers are risk adverse due to the nature of their environment. Personal stockout costs are examined as one of the key factors influencing decision-making and risk adverse behavior. This thesis introduces a conceptual model that describes the Navy inventory management decision-making environment. This model shows the relationship between personal stockout costs, required service levels, cost considerations, and planning horizons across the different decision-making levels in the Navy. This study concludes that readiness-based performance measures must be changed to incorporate a cost focus, and that the risk facing inventory managers due to personal stockout costs needs to be reduced to change their behavior if lower inventory levels are desired.

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I. INTRODUCTION

A. BACKGROUND

The General Accounting Office (GAO) has stated that the Department of Defense (DoD) believes it is better to overbuy items than to manage with just the right amount of stock [Ref.1:p.6]. GAO has also contended that the problem of high inventory levels can be reduced or eliminated through better training of personnel in commercial inventory practices [Ref.2:p.4]. However, recent research has shown that this is not the case [Refs.3,4]. The many differences between the military and private sector, including the unique environment regarding inventory management decisions, have not been considered in GAO's findings.

It is contended in this research that one of the causes of excess inventory is not some general tendency among Navy inventory managers to overbuy items due to a lack of training. It is asserted that Navy inventory managers make rational decisions, seeking to maximize their personal utility in response to the environment they work in. To understand inventory managers' decision-making behavior, it is necessary to understand the environment of rewards and penalties in which they work.

If the personal risks arising from a stockout, or the consequence of a shortage, for example are significantly greater

than the risk of carrying excess inventory to an inventory manager, that greater risk is going to affect a manager's purchase behavior. There are several issues that are unique to the military that contribute to this risk. Specifically, the incentives and penalties, and environmental influences that inventory managers are subjected to with respect to their purchase decisions contribute to a high personal stockout cost, and is a significant factor in motivating their behavior.

This research examines the unique environment and issues that affect inventory manager decision-making, and show the important relationship between stockout costs, service levels and the performance measures that influence behavior. This research discusses the extent to which Navy inventory managers are "risk adverse" in response to their environment with the intent on revealing areas for potential improvement to the system.

B. PREVIOUS RELATED STUDIES

Randle (1996) studied training in commercial logistics practices to improve inventory management in the Navy [Ref.3]. He concluded that training in commercial inventory practices would not appreciably improve inventory management in the Navy, and that many commercial logistics practices are also inappropriate for the Navy. One key reason cited is that the causes of excess inventory are generally unrelated to training.

Some of these causes include: Decreasing requirements due to downsizing and decommissions, lack of asset visibility, lack of customer confidence, contracting regulations, and item manager incentives. Steiner (1996) studied training in commercial logistic practices to improve inventory management in the Army. He also identified that excess inventory was not the result of insufficient or inappropriate training, and discussed similar causes for excess. He concluded that additional training would not improve the military inventory management system [Ref. 4]. Reasons cited include the differences between the military and private sector in the political, economic, legal, and social environment. A summary of the causes of excess inventory as a result of his research is included as Appendix A.

Martin (1996) conducted research on the performance measures and reward structures applicable to DoD inventory management [Ref.5]. She found that the reward system, or incentives in place in DoD inventory management cause inefficiencies, and specifically encourages higher levels of inventory. She suggested additional performance measures such as inventory turnover, total costing, and separate readiness criteria as a means to motivate inventory managers and users to lower on-hand inventory levels by linking these measures to formal rewards available to employees. She concluded that it is necessary that inventory management performance be measured with criteria that support inventory reduction.

This thesis research builds upon the previous studies cited above with the specific focus outlined below.

C. SCOPE OF THESIS

The topic of this thesis is applicable to all of DoD, but it is specifically relevant to the Navy. The focus is on the purchase decisions of secondary items managed by item managers at the Navy Inventory Control Points (NAVICP) in Philadelphia and Mechanicsburg, PA, and the relationship of several factors at various levels in the Navy inventory management hierarchy. The term "inventory manager" is used to describe any manager involved with inventory management decision-making; and includes item managers specifically. This study includes a discussion of the decision-making process inventory managers undertake, and the factors that influence their decisions, such as high stockout costs. Emphasis is placed on the unique environment that the Navy imposes upon inventory decision makers at all levels, as opposed to that in the private sector. Risk adverse behavior is discussed, and its significance is considered in the context of the inventory decision-making environment. Lastly, a model that shows the relationship of personal stockout costs, service levels, cost focus, and decision-making/planning horizon for inventory managers at different levels is presented and discussed.

D. RESEARCH QUESTIONS

This thesis seeks to answer the following questions:

1. Are Navy inventory managers "risk adverse" in their decision-making? If so, why, and what factors contribute to this? (Chapter II)

2. Does the current incentive environment for inventory managers encourage higher levels of inventory? (Chapter III)

3. What is the relationship between stockout costs, service levels, and inventory cost considerations, and how do these affect inventory policy makers, managers, and users throughout the Navy hierarchy? (Chapter III)

4. To what extent are risk and cost considerations incorporated into inventory decisions? (Chapter IV)

5. What changes in the inventory decision-making environment could make managerial decision-making more "risk neutral," and can some factors/issues that affect Navy

inventory manager decision-making be manipulated to encourage different behavior ie. lower inventory levels? (Chapter VI)

E. METHODOLOGY

The author has obtained information from a variety of sources including previous research, unclassified DoD and Navy documents, GAO reports, and relevant published material cited herein. Other data and information were obtained through personal interviews with key personnel including Navy item managers, their supervisors, and policy makers from the Navy Inventory Control Points (NAVICP).

F. ORGANIZATION

This thesis is divided into six chapters. Chapter I provides some background, previous related studies, scope, methodology, and associated thesis research questions. Chapter II is about decision-making under uncertainty with reference to utility theory and risk aversion, and discusses the relevance of utility theory to Navy inventory management. Chapter III discusses personal stockout costs as they apply to inventory management decision-making, customer service levels, safety stocks, and one of the Navy's primary performance indicators for inventory management, Supply Material Availability (SMA) are also

discussed as they relate to stockout costs. A model is presented to show the relationship of these factors over all levels of decision makers. Chapter IV discusses inventory management cost focus, cost versus readiness, risk, and the current incentives and performance measures which influence behavior. These issues are then related to the Inventory Decision-Making Environment Model introduced in Chapter III. Chapter V validates the model presented in Chapter III to determine if it accurately describes the Navy inventory management environment, and Chapter VI presents a summary and the conclusions of this thesis.

II. DECISION-MAKING UNDER UNCERTAINTY

A. INTRODUCTION

One of the many functions of Navy inventory managers is to make purchase and replenishment decisions on secondary items. Although there are a number of tools available to assist them such as EOQ-based mathematical models, much of their decision-making relies upon their experience and subjective judgment. Only changes to their personal risk assessment can create changes in their decision process. This is where the importance of the factors that influence their decision-making is seen.

This chapter will look at basic utility theory and decision-making under uncertainty to provide a backdrop for the subsequent discussion on the factors that influence inventory manager decision-making.

B. UTILITY THEORY

This thesis asserts that Navy inventory managers make rational purchase decisions, and seek to maximize the value of their own personal utility given the environment within which they work. This is the basic hypothesis of utility theory (Bernoulli hypothesis) [Ref.6:p.357]. The "utility" of a decision can include personal career potential, income, job security, pride in performance, or any number of similar aspects

of the job. Utility reflects the value individuals place on the outcome or consequences of their decisions, and one can see that there are a great number of things that can affect or influence an individual's decisions.

Utility in this case can also refer to the satisfaction an inventory manager gets from fulfilling his or her objectives. These objectives include personal benefits that result from doing a "good job" by ensuring the appropriate level of stock is available, or by meeting other objectives such as personal career development and advancement considerations. The environment that an inventory manager works in defines what a "good job" is, and currently in the Navy environment, higher inventory levels mean doing a "better job" [Ref.3:p.67].

The general notion of utility is used in this thesis to explain the idea of risk aversion and its role in an inventory manager's decision-making.

C. RISK AVERSION

A utility function is derived from a relationship between utility and benefit resulting from a decision. The shape of this utility function determines how the individual makes decisions over alternative choices, and depends on many things. For this discussion, the focus is on the individual's relative aversion to

risk when facing the environment surrounding the inventory management decision process.

An individual who is "risk adverse" can be characterized in a simple case as one who would be willing to accept a guaranteed payoff of less than the expected benefit of a particular decision with an uncertain outcome. The degree of risk aversion is related to a decreasing marginal utility for benefits [Ref.7:p.54], as shown graphically in Figure 1:

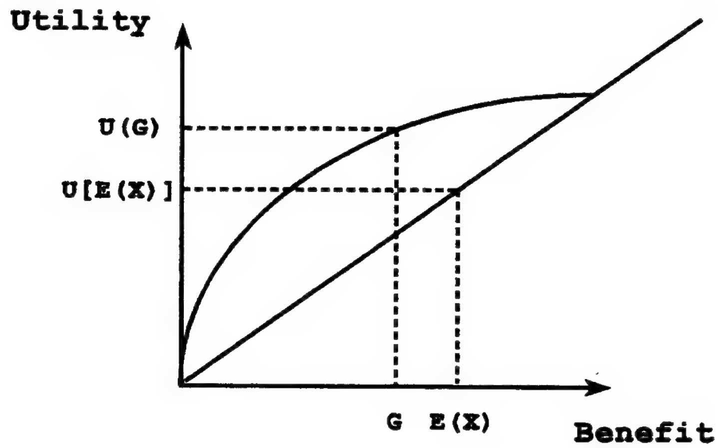

Figure 1: Risk Adverse Behavior versus Risk Neutral Behavior

Figure 1 above graphically depicts risk adverse and risk neutral behavior. The curve represents the risk adverse behavior, whereas the straight line shows risk neutral behavior. It can be seen that point G, which is less of a benefit than the

expected value E(X) of a given decision, actually represents a greater utility to the risk adverse individual than the higher benefit expected value. In contrast, the strait line shows risk neutral behavior where the expected value is the utility maximizing point.

A risk neutral individual in contrast to a risk adverse individual always makes decisions consistent with maximizing expected benefit or value, because their utility will vary linearly with benefit received [Ref.7:p.55]. Many have argued that from an organizational perspective, all decisions should be made in accordance with risk neutrality so that the objective of maximizing expected benefit is achieved [Ref.7: p.55]. However, from an individual perspective, risk aversion is the predominant criteria used for decision-making. Therein lies a potential source of significant disparity between what an organization wants and what a manager implements.

D. APPLICATION OF UTILITY THEORY TO INVENTORY MANAGEMENT

This author contends that the purchase behavior seen by Navy inventory managers is risk adverse. The primary reason for this aversion to risk is the high personal stockout costs encountered by the inventory manager. This risk of stockout is significant because the environment in which inventory management decision makers work creates a "penalty" for a stockout, or low material

availability, that is much greater than the "penalty" for carrying excess stock. This high risk is perpetuated in the performance measures used and the incentive system applied to inventory managers. This environment directly affects an inventory manager's utility function and influences his or her purchase behavior.

If high personal stockout costs or other issues compel risk adverse behavior from inventory managers in their purchase decisions, they may be maximizing personal utility rather than seeking the organization's highest expected value. Consequently their conservative (risk adverse) decision-making may not be the best purchase decisions for a cost and budget conscious Navy. Thus, it is to the Navy's benefit to eliminate, with the appropriate environment, the disparity between these perspectives. In order to facilitate this analysis, it becomes necessary to understand the existing environment facing Navy inventory managers.

E. SUMMARY

This chapter presented an overview of utility theory. Individuals making rational decisions will seek to maximize the value of their own personal utility given the constraints placed upon them by the environment they face. A brief discussion was also presented on risk aversion. These topics are relevant to

Navy inventory manager decision-making since they help describe the fact that although they are making rational decisions in the execution of their jobs, there are external factors that affect their utility function and influence their behavior. This behavior could result in purchase decisions that are not as cost effective for the Navy as they could be. By understanding their decision-making environment, and the factors that compel managers to be risk adverse, one should be able to explain the reasons why inventory levels might be higher than the organization would expect. The primary factors that affect inventory manager decision-making, such as high personal stockout costs, are discussed in Chapter III.

III. STOCKOUT COSTS

A. INTRODUCTION

Stockout costs are the consequence of a material shortage [Ref.8:p.14]. This consequence does not necessarily have to be an economic one. Two different perspectives on stockout costs are distinguished between in this chapter: The organizational costs of a stockout for an item, and the personal costs of a stockout to a decision maker. The focus of this thesis is on the latter, the costs to an inventory manager and how that cost affects their decision-making.

This chapter discusses the environment that managers are faced with, particularly focusing on how personal stockout costs are applied to inventory management decision-making. Customer service levels, safety stocks, and one of the Navy's primary performance indicators for item managers, Supply Material Availability (SMA), are also discussed as they relate to stockout costs. Lastly, a model is developed showing the interrelationship of personal stockout costs, safety levels, and the focus of cost factors in inventory management.

B. PERSONAL STOCKOUT COSTS

A common understanding of stockout costs is that they are an economic consequence of a shortage. The extent of this cost

depends upon the reaction of the customer, or applicable decision maker to the out-of-stock condition [Ref.8:p.14] Different customers, decision makers, and policy makers will experience different costs, and will consequently react differently to a stockout condition.

It is very difficult, from a policy maker's standpoint, to quantify the stockout cost of an item in the Navy. While the private sector can use lost profits or increased costs resulting from backorders, or lost sales to estimate stockout costs, such measures are not applicable in the military. The "cost" of a stockout to the military can be lost readiness or even military defeat including death of personnel.

However, personal stockout costs, which are also difficult to quantify, are key to understanding the influence on inventory manager behavior. Instead of a quantifiable cost such as a lost sale in the private sector, a personal stockout cost implies that an individual's behavior will generate an explicit and direct consequence to them personally. This consequence may not be monetary, but nonetheless it is a cost in that it represents lost benefit to the inventory manager.

For example, an item manager may make a decision to purchase or hold X quantity of a particular inventory item. If this quantity is not sufficient and a stockout results, that item manager may become subject to negative attention for his or her work, perhaps as a result of not meeting the SMA goal or just for

the fact that a stockout did occur. It has been stated that Navy item managers perceive that the worst thing they can do, short of breaking the law, is to run out of stock on an item [Ref.3:p.67]. This situation may have an adverse impact on that item manager's professional reputation or even promotion potential, endangering career security or some other personal cost. Clearly, there is a cost to the item manager for making "wrong decisions"; a cost that a rational, risk adverse decision maker would take action to avoid.

The general condition seen in the Navy is that the penalty or personal cost to the decision maker for a stockout situation is much higher than the penalty for maintaining high or excess levels of inventory to avoid a stockout situation [Refs.3,5]. This is the fundamental concept that suggests inventory managers display risk adverse behavior due to the environment they work in and the incentives that influence their behavior. The degree of risk aversion varies from individual to individual, however the general idea that rational decision makers will avoid these high personal stockout costs is clear.

C. READINESS, SERVICE LEVELS, AND SUPPLY MATERIAL AVAILABILITY

Service levels indicate the ability to meet customer demands from stock immediately, or within a timely manner. When stockout costs are difficult to quantify, such as the case in the

military, often service levels will be set to measure inventory performance [Ref.8:p.232].

1. Performance Indicators

There are a number of performance indicators that are used to measure inventory management effectiveness. One primary problem with the indicators such as supply material availability (SMA), average customer wait time (ACWT), and number of backorders is that they all measure and promote readiness with little or no focus on cost. The result is that the indicators used actually influence behavior by becoming part of the decision-making environment. Decision makers striving to do a good job, and meet goals by achieving performance within a given acceptable range of the performance indicators, will be motivated to do what it takes to be successful in their environment. In these cases, performance indicators that measure readiness will ensure that efforts will be directed towards optimizing readiness (without regard for cost). Several of the key performance indicators and the resulting behaviors found by Randle (1996) are summarized in Table 1.

Performance Measure	Resulting Behavior
Supply Material Avail. (SMA)	Keep higher inventories
Average Customer Wait Time (ACWT)	Cancel documents that cannot be filled quickly
Number of Backorders	Cancel documents that cannot be filled quickly
Number of orders shipped	1. Split large orders and/or 2. Ship small orders first
Pounds of Material Shipped	Ship large or heavy orders first.

Table 1: Performance Measures, adapted from reference 3, p. 67

2. Supply Material Availability (SMA)

A common measure of effectiveness (MOE) for readiness that is directly related to service levels is supply material availability (SMA). Although average customer wait time (ACWT) is becoming more important in evaluating inventory management performance, SMA is still the primary performance indicator for item managers [Refs.3,5], and in the Navy is analogous to customer service level. Navy policy currently is to maintain SMA at 85% on average over all items for most programs. However, budget and funding constraints in FY97 have meant that only 74% to 75% is currently being achieved in many programs, and even less in others [Ref.11]. The goal assumes that 85% of the time, a demand can be filled from stock immediately or in a timely manner. This also means that 15% of the time, there will be a stockout; and consequently, 15% of the time, a decision maker

will be subject to stockout costs. Again, however, due to austere funding this fiscal year (FY97), chances for stockout across all items is much higher, up to 26% [Ref.11].

If it is generally accepted and understood by all stakeholders that 85% SMA is the goal, and that it is "acceptable" to have a stockout 15% of the time, then the established environment facing the decision maker would not be in conflict with the inventory manager trying to achieve that goal. However this is not the case. Funding is a constraint for the item manager at the ICP imposed by policy makers, for example. So, item managers are making utility maximizing decisions at that level to try to achieve an 85% SMA, and satisfy customer demands subject to a budget constraint imposed by policy makers. This begins to describe the much broader context of the problem of service levels versus funding that is examined in the following sections.

D. CONFLICTING OBJECTIVES AND DIFFERENT DECISION-MAKING ENVIRONMENTS

Unit commanders, inventory managers, and other retail, or end users of the items procured by item managers at the Navy ICP have a much different view of what is an acceptable service level. For the end user, the goal with respect to inventory management is to maximize readiness. 85% SMA, or a 15% chance of

stockout, is not consistent with the operator's objective of maximizing readiness. Higher, even 100%, service levels are desired from his or her perspective, and failure to attain the highest possible service levels are viewed harshly by those who are accountable and who are evaluated on the resulting performance. The failure to attain the highest levels of service or readiness will result in increasingly severe consequences. It would surely reflect very poorly on a unit supply officer for example, who fails to have a critical part on hand when it's required in an operational environment where tolerance for this type of failure is close to zero. In the customer's or end user's environment, lives and careers can be at stake.

The service levels expected and demanded by operating commanders approaches 100%; whereas the 85% SMA that is a goal, or the 75% that is currently funded is totally unacceptable to the unit commander, or any other accountable end user of inventory items. This is exacerbated by the fact that current funding levels are driving even lower service levels. It can be seen that a rational decision maker at this level would clearly be willing to "pay more" to avoid these high personal stockout costs, and this understandably leads to higher inventory levels being procured and maintained by risk adverse inventory managers to support the higher service levels required by the end user. The incentives stemming from the environment surrounding policy maker desires, item manager risk adverse decisions, and customer

service level demands are not synchronized to produce harmonious results. The resulting conflicts in the incentives and motivations between these perspectives explains why item managers face such a difficult process.

E. A MODEL RELATING STOCKOUT COSTS, SERVICE LEVELS AND FUNDING CONCERNS

When considering the different levels of management in the inventory process, a general trend can be seen where the service levels desired increase as one descends down the hierarchy from policy makers to the operating forces. Policy makers face a "big picture" perspective, and must not only consider readiness issues, but also be focused on inventory holding/ordering costs, as well as the other budgetary realities in Navy inventory management. The customer/operator however, comes from the perspective of doing "whatever it takes" to support maximum readiness, and will spend accordingly in support of this goal. Therefore, as one moves down the hierarchy, consideration over inventory costs decline, while demand for required service levels increase. Tolerance for failure to achieve high service levels, and the personal stockout costs associated also increase. Lastly the concern for, and focus on, cost and funding to support service levels decrease as one descends down the hierarchy from policy making to the operators.

1. The Inventory Management Decision-Making Environment Model

In general, the service levels expected and desired tend to increase as one descends from policy making to operating forces and end users; personal stockout costs also tend to increase. In contrast, concern or focus for inventory costs and budgetary issues tend to decrease. As one descends through the hierarchy, the decision-making/planning horizon also tends to decrease. At higher levels of management and policy making, the scope is broader and the outlook must consider a greater time range, whereas operators are focused on the day to day activities that characterize the nature of their job. These general relationships can be seen in the model shown in Figure 2.

This model symbolizes the Navy inventory management structure with higher level policy makers at the top and operators to the bottom. Item managers at the ICP are interpreted to be in the middle, facing a decision-making environment that reflects the conflicting incentive structure facing customers and policy makers. Item managers are akin to agents for the customers they serve, as this is their motivation for doing a good job. However, they are also subject to many constraints in how they do their jobs, as they must execute the policies promulgated and achieve the goals set, while being held accountable to established policy and procedure.

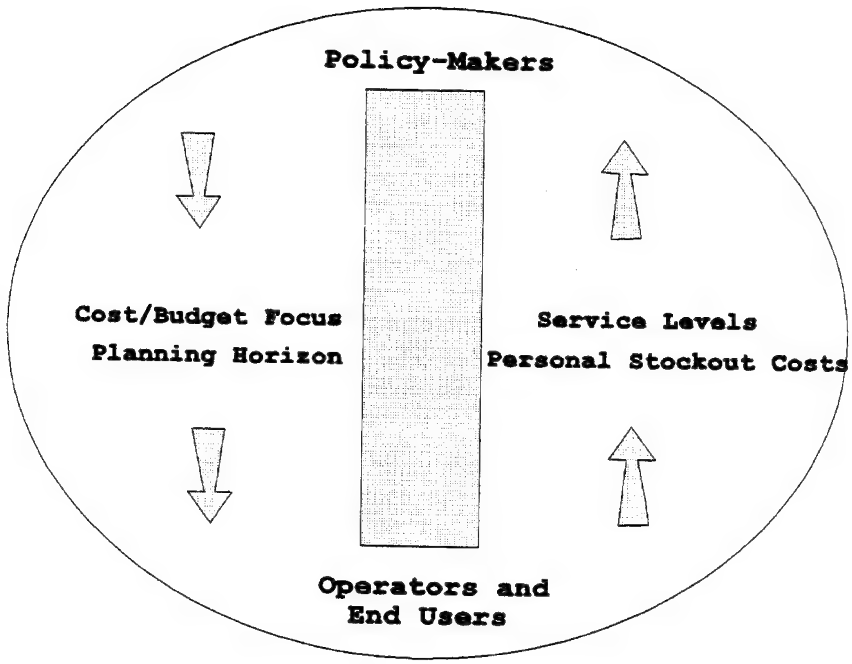

Figure 2: Inventory Management Decision-Making Environment Model

This model shows the important relationship between stockout costs, service levels, and cost considerations at the different levels of inventory management and use.

F. SUMMARY

This chapter discussed stockout costs and their impact on decision makers behavior. The model presented shows that expected service levels tend to increase as one descends from policy makers to the operating forces (end users), and personal stockout costs also tend to increase, while concern or focus on

inventory costs and budgetary issues tend to decrease. And lastly, the decision-making/planning horizon tends to decrease.

There is a relationship between readiness and the primary inventory management performance indicator, supply material availability (SMA). SMA is one surrogate measure of effectiveness for readiness, and decision makers trying to achieve SMA goals or "maximum readiness" will be subject to the personal stockout costs related to not meeting those goals. At the same time, these decision makers also will not be rewarded for saving the inventory costs associated with lower readiness/SMA. Both SMA and readiness have influence over rational decision makers who are reacting to their environments.

The concept described by the model has important ramifications in understanding why decision makers at different levels behave differently and are influenced differently by the same factors.

IV. COSTS, READINESS, AND INCENTIVES

A. INTRODUCTION

The performance indicators and goals related to inventory management tend to measure and favor readiness, with little or no consideration given to inventory cost. Cost concerns are primarily handled at higher policy making levels, and these considerations are generally not conveyed down to lower levels, where decision makers and operators are primarily responsible for, and evaluated on readiness issues, with bigger picture inventory costs not being a concern. This is the primary conflict in perspective.

The Deputy Chief of Naval Operations (Logistics), Vice Admiral William J. Hancock, USN recently stated that:

> (SMA, COSAL effectiveness, and POE) measure our performance, but not always the impact of our efforts... you need to develop performance measures that clearly link funding to ICP, supply system and operating force performance. [Ref.9]

He also stated:

> We can no longer concern ourselves with just making the customer happy... we must risk 'disappointing the customer.' We must be willing to make changes that add risk to our ability to meet previous support standards. [Ref.9]

These statements cut to the heart of the issue of readiness versus funding, and illustrates a real world recognition of the problems created by the existing performance indicators, such as

SMA, that influence undesired behavior like maintaining higher inventory levels. Also revealed here is the acknowledgement of the customer's desire for the highest levels of readiness, and risk-adverse, utility-maximizing inventory management decision makers concerned with ensuring these levels are available to the customer regardless of the cost. Part of the solution must be in integrating desire for the highest possible readiness with frugal stewardship of the Navy's limited budget resources.

This chapter discusses inventory management cost focus, cost versus readiness, risk, and the current incentives and performance measures which influence behavior. These issues are then related to the Inventory Management Decision-Making Environment Model.

B. READINESS VERSUS COST

Most of the key performance measures or "prime indicators" for inventory management effectiveness are based on readiness. They promote higher readiness, and generally do not consider inventory costs or budget concerns. However, budget issues do indeed drive policy making for inventory management.

Navy ICP funding is primarily based on demand, or sales to customers [Ref.9]. The more inventory that fleet customers demand, the more budget dollars that are available to the ICP to fund the purchase and repair of inventory items. There is

currently a particularly tight budget environment throughout the Navy where funding is the primary constraint to what can be done in inventory management. The importance of budget concerns can be seen in its affect on inventory management decisions.

Since the beginning of FY 97, item managers at the NAVICP, Philadelphia have been executing purchases of selected items with no safety levels [Ref. 10]. This means that purchase decisions are based on forecasts from historical demand alone, and that any variation in actual demand will not be able to be met with "safety stock." This decision was made in response to limited funding available to achieve desired inventory (service) levels. Although customer/end user desires were considered in the decision, as the Type Commanders (TYCOMS) were involved with the ICP execution strategy and had input on which items would be fully procured with safety levels and which others would not be, clearly this action would not have occurred if funding had not been such a constraint.

Additionally, customers are currently demanding fewer items, primarily due to funding decreases. This is affecting the Navy ICP in that they may not meet the sales goals and projections that their budgets were based on, and this further complicates their already austere funding environment.

This is just one current example where it is seen that funding alone can drive inventory decision-making. Funding is a

constraint here, but it has not changed the motivations or incentives that influence decision-making.

C. REACTIONS TO FUNDING CONSTRAINTS

Consequences of the decision on safety levels as outlined above are yet to be seen. This is for two primary reasons: First, the effect on repairable items could be negligible since the decision only affects purchases, and not the ongoing repair process. The most significant impact will be on consumable items. Secondly, any effects will not likely be felt until a full procurement lead time has passed for the items concerned, which could be up to 12 to 18 months. However, one can understand that having no safety levels for selected items will eventually affect demand on these items due to customer reaction to increased incidences of shortages.

Considering the model presented in Chapter III, it would follow that increased stockouts as a result of maintaining zero safety levels will elicit different responses from decision makers at different levels. Item managers are currently making "tradeoffs" to maximize readiness on the items under their responsibility with the limited funds that are available. They purchase items that have the greatest positive affect on meeting SMA goals and delay purchases on other items as long as there is no serious degradation of support to the customer [Ref.9].

Customers may respond to a perceived decrease in support caused by item managers being unable to purchase safety level quantities of items by increasing their demand on some items and perhaps maintaining their own safety levels to preclude stockouts. The model illustrates that the operators' required service levels are higher, their personal stockout costs are higher, and their planning/decision-making horizon is shorter, which explains their reaction to low safety stock levels. Item managers, as agents for the customer, respond accordingly in that their desire, or utility maximizing decision-making, is to ensure that the needs of their customers are met.

D. RISK

VADM Hancock's mention of risk in the statement above is a key issue in reducing the disparity between what policy makers accept and fund for inventory in support of readiness, and what the operators and customers of inventory items desire and work towards. Because so many of the inventory management decision makers in the Navy are influenced by readiness-based performance indicators, cost issues become secondary. Operators want to be "up and running" 100% of the time, and have little tolerance for anything less, as this is what they are evaluated on. Item managers, although constrained somewhat by funding and other regulations, as agents for the customer, also desire the highest

possible readiness for customers. Only by removing or decreasing the risk involved with not meeting these objectives, can true improvements be made where cost factors can become important to decision makers.

As the model suggests, these risks are highest for the operators, as the service levels they require, and the stockout costs they incur by not meeting these service levels, are highest. Only fundamental changes in the environment of incentives and penalties can influence these decision makers to accept more risk by accepting lower service levels, and ultimately lower inventory levels. Only a fundamental change in the management environment that influences the benefits and costs of making risky decisions will bring risk adverse decision makers actions in line with policy maker preferences. The acceptance of and interpretation of risk at all levels is therefore key to the inventory management solution.

E. SUMMARY

Important questions in considering cost versus readiness issues include: What is the desired level of readiness, and what level of readiness can the Navy afford? If the answers to these questions are not similar, there is a disconnect. Additionally, there will be different responses to these questions based on who is asked, policy makers or operators, and based on the

environment they must work in. This is the conflict in objectives that makes establishing a coordinated goal for inventory management across all levels so difficult.

Although funding is not a "prime indicator" for inventory managers as is SMA, it can indeed influence decision-making significantly. The problem is, however, simply putting a constraint on funds for inventory is not a viable solution over the long term. Indicators used currently like SMA, number of backorders, and average customer wait time (ACWT) which promote readiness, must also be linked to funding and cost concerns. This focus must become important to the decision makers that implement inventory management decisions so that their utility maximizing decisions include cost considerations. Also, risk must be addressed to reduce personal stockout costs and encourage less risk adverse behavior.

This chapter discussed the issue of readiness versus cost, the importance of funding and risk to inventory management, and showed the relationship between these issues to the model presented in the previous chapter.

V. MODEL VALIDATION

A. INTRODUCTION

Chapter III introduced the Inventory Management Decision-Making Model that showed a disparity in service levels required, personal stockout costs, cost or budget focus, and the planning/decision-making horizon over the inventory management levels in the Navy. The purpose of this conceptual model and the discussion that followed in Chapter IV was to provide an understanding of the environmental factors that influence Navy inventory management decision-making, and what issues must be addressed to facilitate improvements in the system. This chapter discusses the validation of the model to ensure that it adequately describes the actual Navy inventory management system.

B. VALIDATION

Validation is defined as "substantiation that (a model) within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model" [Ref.13:p.104]. Validation has also been described as a "process of reaching an acceptable level of confidence that the inferences drawn from the model are correct and applicable to the real-world system being represented" [Ref.12:p.129]. Although the issues of personal stockout costs, required service levels,

etc... illustrated by this model are difficult to quantify, the description of the decision-making environment that it provides can be evaluated conceptually and intuitively.

Basically, validation focuses on three questions:

> 1. Does the model represent the real-world system? (conceptual validity)
>
> 2. Does the model's ultimate user have confidence in the model's results? (intuitive, believability)
>
> 3. Are the model-generated behavioral data characteristic of the real-world system's behavioral data? (operational validity). [Ref.12:p.147]

The purpose of the model is to show the relationship of service levels, stockout costs, cost focus, and the planning/decision-making horizon over all the inventory management levels in the Navy. The model's adequacy or validity must be evaluated in terms of this purpose, and be judged in relationship to the real system [Ref.12:p.147,8].

The key to this validation process is to determine if the model represents the inventory management decision-making environment accurately. To accomplish this, Department of Navy personnel who are involved with inventory management decisions at various levels were interviewed. Their responses were recorded, and compared on questions dealing with required service levels, personal stockout costs, cost focus, and their planning/decision-making horizons; again, seeking a conceptual validation of the model.

C. DATA

Forty-six Department of Navy (DoN) personnel were interviewed with the questions summarized below, and provided in full in Appendix B. All questions were on a scale from 1 to 9 except for the third question, which asked for a percentage:

1. What is the severity of the penalty or consequence for over-ordering or purchasing excess inventory?

2. What is the severity of the penalty or consequence for under-ordering or purchasing insufficient inventory?

3. What is the service level that you require, or is required of you in terms of material availability percentage?

4. What is the severity of the consequence of not meeting the service level expected or required of you?

5. To what extent would you tend to purchase more inventory to avoid the risk of stockout versus accepting the risk of stockout by purchasing less? 1 being fully avoiding all risk by purchasing whatever is necessary, 9 being fully excepting all risk by purchasing the absolute minimum required.

6. Considering readiness versus cost from your point of view, to what extent does cost or budget considerations play in purchase decisions? 1 being readiness is the overriding concern, 9 being that cost or budget considerations are the overriding concern.

7. What is the typical time horizon you consider with respect to your purchase plans/decisions, or how far out do you "look" in planning and executing your requirements? 1 being day to day, 9 being a year or more.

The questions were designed to query Navy personnel with varied backgrounds and experience in inventory management on the issues and environment described by the conceptual model

presented in this thesis. The focus of the questions was to contrast the different responses of ICP personnel from customers, or end users. The opinions and concerns of high level policy makers including Congress and senior civilian leadership in the Navy are well documented in a number of GAO reports on inventory management [Refs.1,2,14,15,16].

Respondents from "middle-level" inventory management positions consisted of Navy ICP personnel with considerable experience in inventory management including Program Branch Heads, Lead Item Managers (LMS), Item Managers (IMS), and other Inventory Management Specialists with purchasing experience at the ICP level. Their responses to the questions in Appendix B on a scale of one to nine, except for question #3 which is in percentage, were averaged and are presented in table 2. The raw data obtained is presented in Appendix C.

Question #						
1	2	3	4	5	6	7
4.43	6.33	83.1%	6.24	4.71	4.38	8.62

Table 2: Average ICP Survey Responses

The operators and customers (end-users) that were queried also came from a diverse background and had different levels of experience in inventory management. However, most had

significant purchasing, contracting, and/or inventory management experience, and included Supply Corps Officers, Aviation Maintenance Officers, Surface Line, and Special Operations Officers. The averages of their responses are summarized in table 3. The raw data obtained is presented in Appendix D.

Question #						
1	2	3	4	5	6	7
3.68	7.32	94.9%	7.20	3.64	3.36	3.72

Table 3: Average Operator/Customer Survey Responses

D. EVALUATION OF THE DATA

Each question between the ICP and customer personnel was determined to be significantly different at the 95% confidence level assuming a normal distribution of responses. However, a more vigorous method was used to test for statistical significance. The Mann-Whitney U Test, which is a nonparametric rank sum technique, was used [Ref.17:p.604-8]. A spreadsheet program was utilized to rank the data first by group then by observation value, and run the U statistic for each set of data.

A U statistic was computed for each group using the following formula:

$$U=n_1n_2+n_1(n_1+1)/2-R_1$$

Where: n_1=number of customer sample responses
n_2=number of ICP sample responses
R_1=sum of the ranks of customer responses
R_2=sum of the ranks of ICP responses

The mean of the U statistic was computed as:

$$\mu_u = n_1 n_2 / 2$$

And the standard error of the U statistic was computed as:

$$\sigma_u = [n_1 n_2 (n_1 + n_2 + 1) / 12]^{.5}$$

However, to account for observations with tied scores, a correction is used for the standard error. This correction is available for use since the large sample of N=46 represents an approximation to the normal curve [Ref.18:p.124]. The correction for ties is:

$$\sigma_u = ([n_1 n_2 / N(N-1)][N^3 - N/12 - \Sigma T])^{.5}$$

Where: $N = n_1 + n_2$
$T = t^3 - t/12$ (t being the number of observations tied for a given rank)

H_0: That responses are from the same population.
H_a: That responses are from different populations.

Observations were ranked, and any tied observations received the average rank for all tied observations. The U Test value is then compared to the high and low values 1.96 standard errors around the mean to see if there is significant difference

(at 95% confidence) in the observations. Test results are contained in Appendix E.

All seven questions were tested to see if there was a significant difference between the ICP and customer responses, These are U Tests 1 through 7. Additionally, two more tests were completed to see if there was a significant difference between questions one and two for both sets of respondents, These are U Tests 8C and 9I. Seven of the nine tests passed the U Test at a 95% confidence interval, showing there is a difference between the two populations surveyed.

1. Consequences of over ordering.

The results of the first test show that the consequence for over ordering is low for both ICP and customer respondents, and that there is not a significant difference between the two groups.

The ICP respondents showed more of an overall concern for over ordering (4.43) compared to customers with a average response of 3.68, but both these responses were still below the neutral response of 5. This demonstrates that, although there was some recognition of consequence for over buying, it appears that the case of under buying, or insufficient inventory had the most profound consequence to all. This was one of two tests that

did not pass the U Test at a 95% or 90% confidence interval, showing there is no significant difference between the two groups.

2. **Consequences of under ordering.**

The results of the second test show that both groups see high consequences for under ordering, and that there is a significant difference between the two groups. For customers, the consequence for under ordering is significantly higher than for ICP personnel, and this result passed the U Test at a 95% confidence. The ICP concern for supporting the customer is seen in this high average response for the consequence of under ordering (6.33 vs. 7.32). Despite this general feeling among respondents, it was also noted that, other than customer support and their obligation to support maximum readiness, there was perceived less consequence for under ordering, or not having sufficient stock due to the austere funding climate currently being experienced.

Test 8C showed that the customer sees a significant difference between the consequence of over and under ordering, and that the consequence for under ordering is greater for the customer than for ICP personnel. There was a statistically significant spread between the responses on the first two questions within the customer group, again, showing they feel

less of a consequence for over ordering and a greater consequence for under ordering. The U Test confirmed this at a 95% confidence interval.

Test 9I showed that the ICP sees no significant difference between over and under ordering. There was less of a spread between the two questions for the ICP respondents, and the spread implies there may be a difference in the consequences for over ordering and under ordering. However, this difference did not prove to be statistically significant as U Test 9I was the second of the nine tests to fail at the 95% confidence level.

3. Service levels.

The third question dealt with required service levels. Clearly, the customers responded that they required, or were required to have high service levels (94.9%). The 83.1% average that was received from ICP personnel was the result of the respondents' acknowledgement of SMA goals, and actual funding available to meet these goals. Although a small number of ICP personnel responded that 90% or more was the required service levels, most expressed frustration that the funding realities constrained the service levels below what they should be in terms of readiness. The general feeling was that the ICP would support the customer with the highest possible service levels subject to the funding constraint.

Customers on the other hand, expected and required higher service levels. The average expected level of 94.9% however, is clearly out of sync with the currently executed 75%-80% that is funded, or even with the overall goal of 85%. The service levels which are being funded and executed at the ICP level are unacceptably low to the customer. This may reinforce risk adverse behavior, and specifically result in higher demand levels from the customer to compensate for the perceived shortfall in service. The U Test revealed that the average responses for this question were significantly different at a 95% confidence level.

4. Penalty for not meeting service levels.

Both groups of respondents, ICP and customers, noted a significant penalty for not meeting service levels (6.24, 7.20 respectively). This interestingly resembled the average responses received from both on the consequence for under ordering inventory. There appears to be a connection between not achieving (service) goals and the consequence for under ordering according to the respondents. The average responses for this question also passed the U Test at a 95% confidence level.

The general view from ICP respondents was that they try to support the customer to the maximum extent, and it is felt that falling short of that goal has a significant consequence. There was also a considerable response indicating that SMA

specifically, is a particularly important performance measure at this time which is being closely watched, so there was some extra sensitivity to this question.

On the other hand, those who felt a lesser consequence for missing the required service levels stated that because of the particularly austere funding environment, it was "OK" to come up short because "who can really be expected to meet the levels with current funding?" However, again, the majority of respondents from the ICP had a sincere concern for satisfying service levels or SMA, and felt there was a consequence for not achieving that.

The average customer response was also higher than neutral, indicating the importance of service levels, and was even greater than the average ICP response, showing that the consequences are even greater at the customer level as described by the model.

5. Risk of stockout.

Both groups of respondents, ICP and customers, also noted the rational tendency to avoid the risk of stockout by "purchasing whatever is required" (4.71, 3.64 respectively). Again, the intuitive result described by the conceptual model that this would be more pronounced at the customer level proved true. In both cases however, these responses underscored the finding that decision makers tend to be risk adverse in their purchase behavior. The U Test revealed that the average

responses for this question were significantly different at a 95% confidence level.

6. Readiness versus cost.

Both groups of respondents, ICP and customers, stated a tendency towards supporting readiness with respect to budget considerations in purchase decisions (4.38, 3.36 respectively). Again, as described by the model, these responses showed a more pronounced condition at the customer level.

Many of the ICP respondents noted that funding drives the level of readiness in terms of procurement, and had a tendency to give a neutral answer of 5. Also, it is felt that striking a balance between readiness and cost to the best of their ability is their job despite any imposed funding constraint. The average responses for this question passed the U Test at a 95% confidence level.

7. Planning/decision-making horizon.

As expected, there is a significant contrast in the planning/decision-making horizons between ICP personnel and the operator/customer (8.62 vs. 3.72), and the average responses for this question passed the U Test at a 95% confidence level. At the ICP, most decision makers are looking out "at least one lead time away" in planning their requirements, which can be 12 to 24

months for many items. Whereas the customer is more attuned to daily requirements and the consequent need for quicker response.

E. SUMMARY

The results from the number of surveys conducted on both ICP personnel and customers/end users show that the model presented in this thesis does indeed reflect the Navy inventory system accurately, and that the inferences drawn are meaningful. Seven of the nine questions compared for statistical significance passed the Mann-Whitney U Test. This shows that there is a significant difference between the two populations surveyed. Although operational validity was not explored, the conceptual nature of the environment that the model describes was validated.

VI. SUMMARY AND CONCLUSIONS

A. SUMMARY

This thesis discussed the Navy inventory management decision-making environment and several of the key issues that influence inventory management decision makers.

Decision-making under uncertainty, utility theory, and risk aversion were discussed in terms of inventory management in Chapter II. Utility theory illustrated that individuals making rational decisions will seek to maximize the value of their own personal utility given the constraints placed upon them by the environments they work in. There are factors that affect the decision-making and risk taking behavior of rational inventory managers and therefore can influence inventory management behavior. It was also noted that Navy item managers, and decision makers in general, are risk adverse due to the nature of the environment that influences their behavior.

Chapter III described personal stockout costs as a consequence of a shortage that can affect an individual's utility function. This was shown to be a key factor in influencing decision-making and risk adverse behavior in Navy inventory management. The performance indicators that influence inventory managers were discussed and it was shown how they encourage higher levels of inventory. Also, the conflicting objectives

between the different decision-making environments was introduced. A model was presented which showed that expected service levels tend to increase as one descends from policy makers to end users, and personal stockout costs also tend to increase, while the concern for, or focus on inventory costs and budgetary issues tend to decrease.

Chapter IV discussed performance indicators and goals that influence inventory management behavior and tend to measure and favor readiness, with little or no consideration given to cost. Cost focus, cost versus readiness, and risk were all discussed and related to the Inventory Management Decision-Making Environment Model. Lastly, in Chapter V, the questions used in the survey to verifying the model environment passed seven of nine tests for statistical significance using the Mann-Whitney U Test, showing that the model is conceptually accurate in adequately describing the decision-making environment in Navy inventory management at the ICP and end user levels, and that there is a difference between the two populations in the way they perceive their environment.

B. CONCLUSIONS

There are two primary conclusions as a result of this research. They are:

1. The readiness-based performance measures that influence inventory manager behavior must be changed to incorporate a cost focus.

2. The risk facing inventory managers with respect to personal stockout costs must be decreased to change behavior due to risk adverse decision-making.

1. Conclusion one: Performance measures

If reduction of inventory levels is to be achieved, it must not only be made a goal for all inventory decision makers to achieve, but the performance measures that influence and motivate decision makers must be changed to incorporate cost considerations, not just readiness, in purchase decisions.

There is nothing wrong with measuring readiness, for readiness is what the military is about. However, in order to meaningfully reduce inventory levels without degrading readiness as policy makers, such as the senior Navy civilian leadership so adamantly desire, inventory cost concerns must become an internal motivation along with readiness concerns for all decision makers. It is evident from the responses obtained from ICP personnel that controlling inventory purchasing levels with budget constraints is not sustainable over the long term as readiness will clearly be degraded.

2. Conclusion two: Risk

Validation of the model illustrated that there is a considerable aversion to risk. ICP personnel resist failing the customer, and customers are clearly focused on readiness alone. In both cases, there is a high personal stockout cost to not achieving their respective goals. Readiness must be maintained, but the current environment encourages supporting readiness with little concern over inventory costs. Were it not for constraints on funding, decision makers would purchase up to capacity to maximize readiness. However, readiness is currently being determined more by flawed performance measures such as SMA, and not by actual readiness indicators such as "How many planes are up?" The operator is focused on these types of readiness issues, however the personal stockout costs are very high. The readiness-biased decision environment facing inventory managers, combined with their risk adverse behavior, drives the result of "maximum readiness" at any cost. This leads to the phenomenon of "local optimization" where everybody is trying to achieve maximum support for their own operations without regard for expense and inventory cost inefficiencies across the entire Navy.

This is actually rational behavior in that decision makers are doing what it takes to achieve their goals by reacting to the decision environment in which they work in such a way as to be personally successful. Incorporating inventory cost measures

into the performance measures used to evaluate inventory managers would promote a more global perspective.

Changing the performance measures by which Navy inventory management decision makers are evaluated could be achieved by incorporating inventory cost considerations along with readiness measures. The resulting effort to reduce the personal stockout costs experienced by these personnel would generate improvements to the inventory system by effectively maintaining the required levels of readiness, while tackling the necessary task of reducing overall inventory levels and the resulting costs that have recently been under scrutiny by high-level policy makers.

C. FURTHER RESEARCH

This research focused on the Navy inventory managers' decision-making environment and the factors that can influence their purchasing behavior. Areas for additional research suggested by this thesis include developing several cost-based performance measures and incorporating cost factors into the current readiness-based indicators, and testing their potential affect on Navy inventory managers at all levels. Another suggested area is developing initiatives that can reduce risk, or personal stockout costs for decision makers, and testing their potential affect on the Navy inventory management system.

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APPENDIX A. CAUSES OF EXCESS INVENTORY [Ref.4]

CAUSE	EXPLANATION	EXAMPLES
Changes to Requirements Objective (RO)	The predominant cause of excess which encompasses the complete forecast for material and supplies. Forecasting methods at the ICP's may vary however, in general use variations of both the weighted moving average/exponential smoothing and economic order quantity models to determine a forecast of demand. Variability in the procurement cycle is reduced by consideration of other factors designed to compensate for safety, repair cycle, administrative lead times, production lead times, war reserves, and contingency & economic retention points. The result is called the requirements stack (series of all the procurable elements of inventory) which leads to the Requirements Objective or RO. Inventory levels exceeding the RO are considered excess or as DLA calls it, *"Material for Potential Reutilization."*	1) At the retail level, causes encompass a wide range of activities resulting from outdated technical manuals, poor preventive maintenance procedures, faulty quality assurance, poor execution of request turn-in procedures, inadequate catalog/status/ reconciliation measures, training, and more. The following examples are provided. (A) Failure of the unit to turn-in items in a timely manner causes the system to replenish unnecessarily. (B) When units order the wrong part, it later becomes excess. (C) Poor Prescribed Load List (PLL) management by the PLL clerk. (D) Improper ULL's processing (e.g. failure to update the catalogue, not receiving or updating daily status, failure to pick up parts routinely and processing their receipt). (E) Lack of quality assurance checks. The system allows PLL clerks to initiate multiple requests against open/due-in and/or unauthorized parts. (F) Unserviceable parts returned to the vendor may result in the ordering of new parts. The parts may later be determined serviceable and the new items then become excess. (G) Limited capacities at the DS/GS repair levels can result in the item being procured from the wholesale activity versus repair. (H) Restrictive measures on the number of items authorized for turn-in may cause other units in need of the part to requisition new items. (I) Units order repair parts based on anticipated need versus demand history. Funds are the opportunity to get well on current maintenance problems. (J) After requests are passed to the wholesale activity as a dedicated due-in/due-out, there is no method to permit a turn-in to be issued against that requirement and a cancellation of the original requisition to be submitted. Consequently, the item may be on-hand but unissuable. (K) Inaccurate stock location data files. (L) Failure to properly reconcile the monthly reconciliation report provided by the Direct Support Unit. Many units do not work the report in a timely manner, if at all. When they don't work the report, they do not know what is being received, released for issue, or still open, so they may be ordering parts already on order. If a substitute item shows up on the report, they order the part again, thinking it was an error, without checking the AMDF. (M) Requisitions are placed in the system for anticipated requirements (e.g. training, deployments) that don't materialize. Items may be later turned in as excess.

CAUSE	EXPLANATION	EXAMPLES
Changes to Requirements Objective (RO) (cont)		(N) Expiration of shelf life of an item prior to issue causes the item to be re-ordered and the old items now become excess. (O) Off-line requisitions are too easily accessible at the lower levels of supply. Automated requisitions are being processed through normal channels while the same is being ordered through off-line channels (e.g. local purchase, high priority call-ins, manual; walk-through). (P) At the end of each FY, it is a normal practice to hold requisitions due to resource constraints. The increase in the order ship time (OST) will cause stockage levels to increase. This will result in the expenditure of funds to fill the RO. When OST returns to normal, the RO drops and the items become excess. 2) Changes in retail demand; any of the factors relating to safety, repair cycle, administrative lead times, production lead times, war reserves, and contingency & economic retention points; and to the National Military Strategy can effect inventory levels. Cancellation of procurements may not be economical or possible.
Lack of Asset Visibility	Refers to the inability to see inventory assets either laterally (across military components e.g. DLA, NAVICP, AMC) or vertically (from the depot/distribution activity to the user level). Created by stovepipe systems which are tailored meet the specific needs of the individual users. There is a black hole between the ASL and PLL. These systems do not interface. They don't use common data elements. The lack of asset visibility limits the ability to match assets with requirements. Leads to a large number of multiple use items/redundancy in procurement actions.	1) Many DLA weapon system support items are multiple use. -Army 43% -Navy 21% -Air Force 34% -Marine Corps 73% Without knowing the total assets and requirements, the ability of DLA to provide timely weapon system support in a crisis is at risk. Redundancy occurs. For example, filters needed to support one component may be sitting in another components warehouse. However, new filters will be procured to support the requirement. DLA cannot see the filters are sitting on the shelf within the other activity. 2) 69 Modular radio transmitters owned by the Army and stored at Warner Robbins AFB valued at approximately $14,000. The Air Force had made no attempts to get disposition authority from the Army. 3) Inhibits the ability to match excess inventories previously sold to DRMO with current requirements. For example, wiring harnesses previously sold to DRMO may later be required due the extended life of systems. 4) Loss of accountability of in transit assets at all levels. For example, in the Army, assets (turn-ins and receipts) are processed and become redistributable daily. At this point visibility and accountability are lost. Items on hand are dropped from the DS/SARRS ABF files for turn-in to the next higher level and due-ins are not established at that level. Another request may be received which causes either a passing action or replenishment requisition. A unit ordering a part or an authorized stockage list (ASL) replenishment document will not have the opportunity to capture an issue from an in transit asset. Requisitions in turn go the wholesale activity and new parts are procured. When the in transit parts are received, they become excess to the needs of the division or installation.

CAUSE	EXPLANATION	EXAMPLES
Lack of customer confidence	Caused by undue Command influence stemming from a philosophy of *"Readiness At Any Cost."* The emphasis at the unit level is on readiness. The *"Firstest With The Mostest"* is the winner concept. Individual Commanders are rated on readiness, so their policies lean toward quick inspections and inflated demand. Customers do not trust the system to provide what they need. Material availability plays a significant role in readiness capability. Procurement specialists may over-order and hoard supplies (just in case inventories). The result is bottlenecks, procurement delays, and new excess material.	1) Order three to insure one. During Operation Desert Storm, lessons learned indicate the 24th Infantry Division was provided three weeks notice prior to deployment of the first combat units. The emphasis on material availability resulted in procurement specialists placing orders two and three times to insure receipt of the item. The resulting strain on the supply system was sufficiently great to severely impede the ability to support later deploying units. The problem was compounded as other units repeated the process. By the time the system was able to recover, over 40,00 Sea land Containers were delivered to Saudi Arabia. Only about half of these containers were ever opened. 2) Generally, users have a low opinion of and little confidence in the logistics system. Therefore, they plan on self sufficiency.
	Additionally, the current system of credits for turn-in of repairables at the retail level serves as a dis-incentive. Many items do not receive full credit. The users incentive is to retain the item.	1) In some cases, it may be more advantageous for retail procurement specialists to hide material versus turning items in for credit. Why turn an item in and receive 80% credit when you know you will be ordering it again in the near future.
Force Modernization, Product Modification, and Life of Type Buys.	During initial procuremnents, sometimes the contractor makes the wrong guess on the number of lines to support system. MTBF may vary from the estimates. The contractors incentive is to maximize the Interim Support List (ISL). The greater the number of lines on the contractors ISL, the greater the profit. Design instability of new weapons systems may result in product modifications. Modifications may render the initial spares obsolete. Life of Type Buys refer to the procurement of all the spares necessary to support the weapons systems during its projected life cycle. The goal is to ensure DOD's capability to maintain support for the system long after the contractor production facilities have shut down. Many of these spares may never be used.	1) The first two years of a new weapon system are basically an engineers best guess. The defense contractor for the B-2 bomber recommended 6,000 line items to support the initial procurement of spares for the aircraft. Of these 6,000 items on the contractors ISL, only 400 have been used to date. 2) 13 modernization kits for the P-3C aircraft valued at $4,480 each and stored at the Fleet Industrial Supply Center, Norfolk, Virginia have been in storage since 1978. 3) There are 7 obsolete clutch assemblies previously used on the M125 10 ton Prime Mover and valued at $5,334 stored at the Defense Supply Depot, New Cumberland, Pennsylvania 4) Results in an attitude that if you can't buy it back cheaply, don't dispose of it. There's a lot of private junkyards that will be happy to sell it back to. 5) Aircraft vanes and blades can be repaired for a while. However, when they finally need replacement, there's no demand in the system. 6) DLA's goal is an 85% supply material variability rate for major weapons systems support.

CAUSE	EXPLANATION	EXAMPLES
BRAC consolidation & closings	Research indicates consolidation and closings always identify inventory not on the accountable records. Therefore, inventories may exceed the Requirements Objective. Items at a BRAC'd base stratify to excess after 2 years.	1) DLA closings at Memphis, Utah, & Columbus resulted in excess. 2) Letterkeny states the lack of people/ manpower has pre-empted their ability to conduct a full inventory since 1986. *"We'll find a lot of inventory we didn't know we had when we close down."*
	Loss of trained IM personnel.	1) At the US Army, Training and Doctrine Command installations, the drawdown resulted in a number of inexperienced item managers taking the exit bonus and leaving the federal workforce. New/inexperienced item managers (GS-5) entered the workforce. Training is dependant on funding and priorities. Still further, DLA indicates they have received no interns within the last 5 years. About 2/3's of their workforce will retire within the next ten years. 2) At the Defense General Supply Center, Richmond, the number of lines item managers manage doubled, while the number of managers declined.
Support of Allies	DOD's requirement to support Allies (Foreign Military Sales or FMS) results in the retention of unnecessary or obsolete equipment. Wholesale activities must be able to support requisitions for FMS spares NLT 330 days after submission.	1) The Army began replacing the Commercial Utility Tactical Vehicles (CUTV) with High Utility Mobile Vehicles (HUMMV) during the early 90's. CUTV's were turned in (on a one for one basis) to the supply system as the vehicles were fielded. These vehicles currently are sitting at the Defense Depot Distribution Center, Letterkenny, Chambersburg, Pennsylvania in anticipation of future FMS contracts. 2) Approximately 100 short barrel, towed, 105mm howitzers left over from the Vietnam War await disposition at the Defense Depot Distribution Center, Letterkenny, Chambersburg, Pennsylvania in anticipation of future FMS contracts. 3) FMS sales of Patriot Missile Batteries requires DoD to maintain 5 variations (w/supporting spares) of the equipment. 4) South Korea makes 155mm howitzer ammunition which they sell to foreign countries. However, their support for internal defense of the country comes from the US. Their soldiers defend over 3/4's of the line separating the North from the South. 5) G-Grant: Refers to the concept of giving inventory away to Allies that cannot afford to pay. For example, the recent fielding of obsolete aircraft to Jordan. The US will retain a certain amount of spare part inventories to support future requirements for these aircraft. 6) There are 2 electric pumps costing $45,000 each for destroyer class ships no longer in service retained at the Fleet Industrial Supply Center, Norfolk, Virginia. 7) There are 3 obsolete equalizers assemblies costing approximately $75,000 for the F4 aircraft reconnaissance system retained at the Warner Robbins Air Logistics Center, Warner Robbins Air Force Base, Georgia.

CAUSE	EXPLANATION	EXAMPLES
Economic and Environmental Issues	Certain items can have an adverse impact on the environment or economy.	1) The Defense Distribution Center, Letterkenny, Pennsylvania retains stockpiles of various ores (e.g. asbestos, lead, nickel, TALC, and zinc) which have not been disposed of. There are both environmental and economic issues to be addressed. For example, sales on the open market would have an adverse impact on the market price. The Depot has approximately 137,967.9 tons of the material occupying some 1.1 million square feet of open storage space.
Ineffective DOD Item Manager Controls	DOD Item Managers sometimes prematurely and unnecessarily purchase wholesale inventory of consumable items and do not always make the most prudent decisions. Controls should focus on: verification of requisition demand coding, analysis and evaluation of demand trends, development of acquisition lead times for consumables, and improvement of controls over reevaluating purchase decisions	1) A DoD Inspector General report dated 9 November 95 indicates ICP's were prematurely and unnecessarily ordering wholesale inventories of consumable items. The reports states the conditions occurred because management controls were ineffective and did not ensure that inventory managers always made the most prudent decisions. The report concluded that of the $1.06 billion of consumable items that ICP's were in the process of ordering (contracts not yet awarded in April 1994), consumable material valued at $126.6 million (11.9 percent) exceeded current requirements. Of this amount, approximately $88.9 million was premature and $37.7 million was unnecessary. Therefore, ~~the~~ avoidable cost associated with carrying the inventory was placed at $59.6 million.
AMC/DLA ALT/PLT Leadtime Reduction Efforts	As wholesale activities reduce the administrative and procurement leadtimes through improved efficiency, the quantity of safety inventories required to reduce variability decreases. Failure to adjust the mathematical models for the CCSS and SAMMS would result in excess inventories. The average cycle time for the Army procurement cycle is 23 days. The Army is implementing a number of initiatives to reduce cycle time to 3 days.	1) DLA and AMC reductions in ALT/PLT have resulted in procurements exceeding the RO.

APPENDIX B: QUESTIONS USED DURING VALIDATION

1. What is the severity of the penalty or consequence for over-ordering or purchasing excess inventory?

On a scale from 1 to 9, 5 is the neutral response: 1, being no penalty or consequence such as "Nothing happens" to 9, being the highest penalty or consequence such as "I get fired."

2. What is the severity of the penalty or consequence for under-ordering or purchasing insufficient inventory?

On a scale from 1 to 9, 5 is the neutral response: 1, being no penalty or consequence such as "Nothing happens" to 9, being the highest penalty or consequence such as "I get fired."

3. What is the service level that you require, or is required of you in terms of material availability percentage?

4. What is the severity of the consequence of not meeting the service level expected or required of you?

On a scale from 1 to 9, 5 is the neutral response: 1, being no penalty or consequence such as "Nothing happens" to 9, being the highest penalty or consequence such as "I get fired."

5. To what extent would you tend to purchase more inventory to avoid the risk of stockout versus accepting the risk of stockout by purchasing less?

On a scale from 1 to 9, 5 is the neutral response: 1, fully avoiding risk by purchasing whatever is required, to 9, fully accepting all risk by purchasing the minimum to save funds.

6. Considering readiness versus cost from your point of view, to what extent does cost or budget considerations play in purchase decisions?

On a scale from 1 to 9, 5 being the neutral response: 1, readiness is the overriding concern, to 9, cost/budget considerations is the overriding concern.

7. What is the typical time horizon being considered with respect to your purchase plans/decisions, or how far out do you consider in planning and executing your requirements?

On a scale from 1 to 9, 5 being the neutral response: 1, day-to-day, to 9, a year or more.

APPENDIX C. ICP SURVEY RESPONSES, RAW DATA

Respondent	Question #						
	1	2	3	4	5	6	7
A:	4	7	74	8	5	5	9
B:	6	8	75	7	3	6	9
C:	7	7	80	8	5	6	8
D:	3	6	85	4	4	3	9
E:	4	6	80	4	3	5	9
F:	3	7	85	7	7	5	9
G:	4	5	100	7	2	2	9
H:	5	8	75	6	4	7	9
I:	3	5	87	6	6	6	9
J:	6	8	80	8	6	3	9
K:	5	7	80	7	6	3	9
L:	2	6	80	5	4	3	9
M:	5	6	80	6	5	6	9
N:	2	5	85	6	5	3	9
O:	3	7	80	5	4	4	6
P:	6	6	85	6	5	4	9
Q:	6	8	100	8	5	4	9
R:	5	4	85	3	3	3	9
S:	5	7	84	6	5	5	5
T:	6	7	85	7	5	3	9
U:	3	3	80	7	7	6	9
Totals:	93	133	1745	131	99	92	181
Mean:	4.4286	6.3333	83.095	6.2381	4.7143	4.381	8.619
Std. dev.:	1.4687	1.354	6.7075	1.4108	1.3093	1.431	1.0713
Std. error:	0.3205	0.2955	1.4637	0.3079	0.2857	0.3123	0.2338

APPENDIX D. CUSTOMER SURVEY RESPONSES, RAW DATA

Respondent	Question #						
	1	2	3	4	5	6	7
A:	2	7	85	6	3	3	3
B:	1	7	90	7	2	2	3
C:	6	8	95	7	2	3	3
D:	4	7	95	7	3	4	3
E:	2	7	100	7	3	3	5
F:	3	8	95	8	3	4	5
G:	3	7	100	7	7	5	8
H:	5	8	85	7	6	5	2
I:	5	8	98	8	5	1	1
J:	4	6	95	9	4	3	5
K:	3	8	99	7	4	3	1
L:	2	8	95	8	3	2	3
M:	3	8	95	8	4	3	5
N:	5	5	95	5	4	6	4
O:	5	7	90	9	3	4	5
P:	6	7	94	7	2	2	5
Q:	3	7	95	7	1	1	5
R:	5	8	100	8	5	5	5
S:	4	7	100	9	3	1	3
T:	5	8	95	5	7	7	3
U:	2	8	90	6	1	1	3
V:	1	7	95	7	5	5	3
W:	5	8	95	6	5	3	6
X:	5	7	98	7	2	5	1
Y:	3	7	98	8	4	3	3
Totals:	92	183	2372	180	91	84	93
Mean:	3.68	7.32	94.88	7.2	3.64	3.36	3.72
Std. dev.:	1.4922	0.7483	4.1765	1.0801	1.6299	1.6299	1.6713
Std. error:	0.2984	0.1497	0.8353	0.216	0.326	0.326	0.3343

APPENDIX E. MANN-WHITNEY U TEST RESULTS

Group	Obser	Rank	Group	Obser	Rank	
C	1	1.5	I	2	5.5	1
C	1	1.5	I	2	5.5	2
C	2	5.5	I	3	14	3
C	2	5.5	I	3	14	4
C	2	5.5	I	3	14	5
C	2	5.5	I	3	14	6
C	3	14	I	3	14	7
C	3	14	I	4	22.5	8
C	3	14	I	4	22.5	9
C	3	14	I	4	22.5	10
C	3	14	I	5	32	11
C	3	14	I	5	32	12
C	4	22.5	I	5	32	13
C	4	22.5	I	5	32	14
C	4	22.5	I	5	32	15
C	5	32	I	6	42	16
C	5	32	I	6	42	17
C	5	32	I	6	42	18
C	5	32	I	6	42	19
C	5	32	I	6	42	20
C	5	32	I	7	46	21
C	5	32				22
C	5	32				23
C	6	42				24
C	6	42				25

	N	R	
A	25	516.5	
B	21	564.5	
U STAT	333.5	*5% SIG*	
MEAN	262.5	1.96	349.41
StdErr.	44.34		175.59
(corr.)		*10% SIG*	
		1.645	335.44
			189.56
SUM T=	355.5		

Ho: No difference between the populations.

Ha: A difference between the populations.

Note: The rank sum test for each question was completed on a similar spreadsheet. However, the results for tests two through nine are summarized on the following page.

APPENDIX E. MANN-WHITNEY U TEST RESULTS

	N	R		
C	25	754		
I	21	374		
U STAT	96	*AT 5% SIG*		
MEAN	262.5		1.96	346.45
StdErrc	42.83			178.55
		AT 10% SIG		
			1.645	332.96
Test 2				192.04

	N	R		
C	25	843		
I	21	285		
U STAT	7	*AT 5% SIG*		
MEAN	262.5		1.96	350.19
StdErrc	44.74			173.81
		AT 10% SIG		
			1.645	336.1
Test 3				188.9

	N	R		
C	25	687.5		
I	21	393		
U STAT	162.5	*AT 5% SIG*		
MEAN	262.5		1.96	348.27
StdErrc	43.76			176.73
		AT 10% SIG		
			1.645	334.49
Test 4				190.51

	N	R		
C	25	480		
I	21	601		
U STAT	370	*AT 5% SIG*		
MEAN	262.5		1.96	349.68
StdErrc	44.48			173.32
		AT 10% SIG		
			1.645	335.67
Test 5				189.33

	N	R		
C	25	494		
I	21	587		
U STAT	356	*AT 5% SIG*		
MEAN	262.5		1.96	349.23
StdErrc	44.25			175.77
		AT 10% SIG		
			1.645	335.29
Test 6				189.71

	N	R		
C	25	333		
I	21	748		
U STAT	517	*AT 5% SIG*		
MEAN	262.5		1.96	347.86
StdErrc	43.55			177.14
		AT 10% SIG		
			1.645	334.14
Test 7				190.86

	N	R		
C	25	332		
I	25	943		
U STAT	618	*AT 5% SIG*		
MEAN	312.5		1.96	411.85
StdErrc	50.69			213.15
		AT 10% SIG		
			1.645	395.89
Test 8C				229.11

	N	R		
C	21	484.5		
I	21	596.5		
U STAT	187.5	*AT 5% SIG*		
MEAN	220.5		1.96	297.18
StdErrc	39.12			143.82
		AT 10% SIG		
			1.645	284.85
Test 9I				156.15

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